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(54) Title: RADIO COMMUNICATION SYSTEM

(57) Abstract

Data transmissions take place in a radio communication system between at least one base station and at least one remote station. The base station is able to transmit signals to and receive signals from the remote station whilst the remote station is in a predetermined area. A priority is assigned to each type of data to be transmitted and the type and priority of each forthcoming transmission is determined and stored. Data types of the highest priority are then transmitted prior to data types with lower priorities. Where there is more than one base station there will be a plurality of overlapping communication cells. The base stations broadcast signals in a first time period and remote stations transmit signals in a second time period. The base stations are coupled to a central controller which synchronises the first and second time periods used by the base stations in adjacent cells. The number of transmissions in each cell is monitored and the durations of each of the first and second time periods adjusted to improve the use of available transmission bandwidth. Transmissions from remote stations to base stations may be transmitted after a predetermined delay which is varied in dependance on the distance of the remote station from the base station.

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RADIO COMMUNICATION SYSTEM

FIELD OF THE INVENTION

This invention relates to a radio communication system and in particular to such a system for use with a local area network having at least one receiver transmitter unit connected thereto for communication with one or more wireless mobile units.

BACKGROUND TO THE INVENTION

The invention has been developed in the context of an Asynchronous Transfer Mode (ATM) networking infrastructure using radio communication which is capable of supporting multi-media data traffic at rates from 25 Mb/s to 2.4 Gb/s in local and wide areas. However, the invention could also be used with other networking infrastructures.

In a standard ATM network, all units operating on the network are connected thereto by cable. There has, however, been an increasing demand for mobile units to be able to communicate with a network. These can be articles such as laptop and notebook hand-held computers, cameras, etc. A basic wireless network system is described in our paper entitled "The ORL Radio ATM System, Architecture and Implementation" dated 16 January 1996 and published on our Website at www.orl.co.uk.

In the system we have proposed, the network has a number of base stations or Access Points (AP) connected to a standard wired network and a plurality of mobile stations or Wireless Terminals (WT) connected to e.g., notebook and laptop computers which may be portable.

Figure 1 shows schematically a set of Access Points and Wireless Terminals operating in the network. The network 2 has the Access Points 4 connected to it. The

Access Points themselves are physically separated and each is able to transmit and receive messages over a limited range e.g., up to 30 metres. The area covered by transmission to and from a single Access Point is called a pico-cell 6. The pico-cells overlap to ensure that all desired areas are covered by the radio system. The channels with which the Access Points 4 transmit and receive messages are selected so that adjacent Access Points use different radio channels and thus do not interfere with each.

Wireless Terminals 8 operate within the pico-cells 6 and are able to move from pico cell to pico cell. They transmit and receive data from the Access Point 4 controlling the pico cell they are in. When they approach a boundary with an adjacent pico cell, a handshaking and cross-over operation takes place as they move to the adjacent pico cell and start to transmit and receive in the radio channel of that pico cell.

A number of Access Points are located in a building to provide full coverage.

Each Access Point communicates with the Wireless Terminals in its pico-cell using a frame transmission structure. The frame structure provides time division multiplexed access to the radio channel. The frame is divided into two sections: during the first the Access Point transmits, during the second the Wireless Terminals may transmit.

The Access Points transmits firstly a preamble comprising a frame description message followed by a number of data and control messages. During the period reserved for Wireless Terminals, a number of different Wireless Terminals may transmit. These transmissions comprise data and control messages. Wireless Terminals

are assigned time slots in which to transmit data messages. Wireless Terminals can be assigned specific periodic time slots in which to transmit. The Access Points and Wireless Terminals exchange request and allocation messages to assign future time slots to a WT.

In addition to assigning time slots to particular transmissions, the Access Point must assign priorities to different data types and must manage the allocation of time slots in accordance with this. Some data types such as voice data require a high priority to ensure that there is no break in a real-time transmission being sent over the radio link. Managing such a scheme presents various problems in a radio communication scheme.

There is a further problem in such systems in that it is difficult to predict the split between upstream traffic (WT to AP) and downstream traffic (AP to WT). This will depend on the requirements of users at any one time. With a fixed frame structure this prevents full use of the available bandwidth, particularly when there are a small number of WT's within the range of an AP.

This can be overcome by using a variable frame length, dependent on the total amount of traffic, and a variable split between upstream and downstream data traffic. However, because adjacent AP's have overlapping areas of coverage this will lead to problems with crosstalk between units in the system.

A further synchronisation problem arises because some WT's are further away from the AP than others. This means that nearby WT's receive data from the AP first. If these assume the same delay between AP to WT and WT to AP transmissions as remote WT's, this will result in lack of synchronisation in WT to AP transmissions.

SUMMARY OF THE INVENTION

A preferred embodiment provides a scheme for assigning time slots to data transmissions in accordance with the priority given to the data type for transmissions from AP's to WT's and from WT's to AP's. This scheme can be implemented using Field Programmable Gate Arrays (FPGA's) and memory. It assigns slots WT by WT and prioritises transmissions for each WT.

A further embodiment provides a scheme for synchronising the frame structures used by adjacent Access Points, i.e., giving each AP the same frame length and split between upstream and downstream traffic and synchronising transmissions. However, the frame structure (length and split) can be changed as the requirements of users in terms of data transmissions change, thereby getting optimum usage of the available bandwidth.

Preferably, WT's which are close to an AP insert a variable delay prior to transmitting data to the AP to synchronise that transmission with data transmitted by WT's more distant from the AP.

The invention is defined in its various aspects with more precision in the appended claims to which reference should now be made.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in detail, by way of example, with reference to the drawings in which:

Figure 1 is a schematic diagram of network Access Points and Wireless Terminals for use in an embodiment of the invention and as described above;

Figure 2 shows a timing diagram for a series of frames received and transmitted by a WT and AP of the scheme of Figure 1;

Figure 3 shows a table stored in memory for prioritising transmissions;

Figure 4 shows a register bank used in conjunction with the table of Figure 3 for scheduling transmissions; and

Figure 5 shows a set of synchronised frames transmitted in adjacent pico-cells.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Data Transmissions

The form of data transmissions between the Access Point 4 and the Wireless Terminals 8 is best understood with reference to Figure 2. The transmissions comprise a series of frames each having a a downstream portion in which an upstream Access Point 4 broadcasts to the WT's in its pico-cell followed by a period during which Wireless Terminals can transmit to the Access Point. Null periods (TTn) are provided during which the Access Point and the Wireless Terminals switch between receive and transmit modes. In Figure 2, the left-hand column shows what is happening at a WT and the right-hand column shows what is happening at an AP. The lighter shaded portions are AP to WT transmissions and the darker shaded portions are WT to AP transmissions.

The identifiers used in the example of Figure 3 are as follows:

TTO:	WT to AP turnround time
PRE:	Access Point Preamble (not illustrated)
FD:	Frame Descriptor Map
RG:	Reservation Grant
DACK:	Downstream Acknowledgement
DCELL:	Downstream Data cell Transmission
TT1:	AP to WT turnround time

RR: Upstream Reservation Request

UACK: Upstream Acknowledgement

UCELL: Upstream Data cell (start of burst)

In this example, the first portion of a frame comprises a Preamble (PRE - not shown) followed by a Field Descriptor (FD) which is broadcast to all the mobile units within the pico-cell 6 controlled by a particular Access Point 4. This frame descriptor advises all the Wireless Terminals 8 of the subsequent format and duration of the frame.

Following the frame descriptor, there is a Reservation Grant slot (RG) which is used to advise WT's which ones have contended for and been granted a future transmission slot in a frame for transmission of data to the Access Point. This is an acknowledgement of a Reservation Request and advises the WT of the number of data cell transmission opportunities it currently has allocated. This is the basic information contained in every transmission from an Access Point to the Wireless Terminals. This may be followed by a Downstream Acknowledgement (DACK) of an Upstream Data cell transmission from a mobile and a Downstream Data Cell transmission (DCELL).

There then follows a null period (TT1) during which the Access Point switches from transmit to receive mode and the Wireless Terminals switch from receive to transmit mode. Wireless Terminals 8 can then transmit Upstream Reservation Requests (RR) in the next slot of the frame. If more than one terminal sends an Upstream Reservation Request at the same time, there will be contention and the Reservation Requests may be lost. This may then be followed by an Upstream Acknowledgement of downstream data

cells and by any Upstream Data Cells (UCELL) to be transmitted.

There is then a further null period whilst the Access Point switches back to transmit mode and the Wireless Terminals switch back to receive mode before commencement of the next frame. The above is the basic frame structure.

As can be seen, the minimum frame is:

- TT0 PRE FD RG TT1 TT0.

A reservation request looks like this:

- TT0 PRE FD RG TT1 RR TT0 PRE FD RG TT1.

A burst of 4 data cells from one mobile looks like:

- RG TT1 rr UCELL(x4) TT0 PRE FD RG DACK TT1 ....

The process continues indefinitely.

Immediately preceding the Field Descriptor is a preamble portion (not illustrated). This comprises some basic housekeeping information such as synchronisation data. The Access Point and Wireless Terminals use the preamble to synchronise reception and adjust automatic gain control for reception.

When an AP receives a Reservation Request it responds with a Reservation Grant transmission as described above. This means that a time slot has been allocated to the mobile. The WT is subsequently advised of this in a permission to transmit message included in the FD of a subsequent frame and then transmits a predetermined number of data cells in that frame. If the WT has more data cells than can be accommodated in that particular frame, a further permission to transmit message will be included in a subsequent frame. This will continue until the WT has sent all its data.

Prioritising Transmissions

The manner in which an AP deals with data transmissions having different priority is illustrated with reference to Figures 3 and 4.

The AP stores in its local memory a table of the type shown in Figure 3. This comprises for WT to AP and for AP to WT transmissions records of the data types which can be transmitted (DTN). A Flag F indicates whether or not a particular WT has requested or requires a transmission for each data type in an upstream or downstream transmission, and N is the number of data cells required for that particular transmission.

The data types have different priorities. This example shows only 3 data types but more could be used. DTI has highest priority and DT3 lowest priority. Entries are made in this stored table for every forthcoming transmission. Entries in the table correspond to a reservation and this may correspond to any number of transmissions. The reservation is maintained and continues to generate transmission opportunities until it is removed by the WT.

Every time a new entry is made in the table of Figure 3, a corresponding entry is made in a register bank illustrated in Figure 4. This comprises a shift register for each data type for both upstream and downstream transmissions. Thus, the columns representing the shift registers in figure 4 correspond to the columns of the table of figure3. These registers are used to form a queue of forthcoming transmissions in the order in which they were requested.

Counters are provided with the register bank to point to the start and end points of entries in the register for each data type. This is to ensure that new entries are

entered in the correct place. The register operates as a first in first out (FIFO) register.

When allocating data cells in a frame, the Access Point will first allocate the earliest requested highest priority transmission from a WT. In the example given this is a request from WT4 for an upstream transmission and an allocation to WT5 on the downstream transmission. Data cells will be allocated in the Field Descriptor on the next frame and data transmitted. On the following frame the highest priority DT1 requests are both by WT3 and data cells will be allocated accordingly. The number of data cells is taken from the table of Figure 3 which is stored in memory. There will be no allocations of data cells to DT2 and DT3 type data on either upstream or downstream transmissions until all the DT1 allocations have been dealt with respectively. After these have been dealt with, DT2 data is then transmitted. When there is none of this outstanding, DT3 type data will be transmitted. Thus, data is prioritised and scheduled to ensure optimum transmission.

If the number of data cells a particular WT requires to transmit exceeds that available in a single frame, excess data cells will be held over until the following frame. If there are repeated requests for DT1 transmissions on upstream or downstream to the extent that DT2 and DT3 will never be transmitted, the system can be modified to ensure that there will be periodic transmissions of DT2 and DT3 type data to ensure that these do eventually get through.

The scheme can be implemented in a straightforward manner using Random Access Memory, a bank of registers and FPGA's and suitable control circuits or could be implemented using software control.

An additional entry shown in the table of Figure 3 is for the antenna to be used on transmissions between the AP and each WT. Preferably, the AP is provided with at least two antennas and periodically tests the quality of transmissions to each WT in its particular pico-cell. A value representing the antenna which gives best communication with each WT is then stored. This information is then used for upstream and downstream transmissions between the AP and each WT.

This entry can be changed if any of the WT's move.

Some WT's will generate data at fixed rate, e.g., audio data. In order to accommodate such data the scheme can be modified such that the AP pre-allocates time slots for that type of data transmission and uses this in addition to the queueing of data types shown in Figure 4. The table of Figure 3 can be extended to include entries for WT's which require constant bit-rate transmissions on the upstream or downstream side. An entry for such a transmission can then be made in every frame to ensure that there is no loss of data.

Variable Frame Structures

As explained above, problems can occur with interference between transmissions in adjacent pico-cells, particularly when variable frame lengths are used and transmissions in adjacent pico cells are not synchronised. This can occur even when the frequency used in adjacent pico cells are different and the isolation between channels is limited.

We have appreciated that this problem could be overcome by providing synchronised frame structures for adjacent pico-cells, i.e., transmissions in each pico cell that start and end at the same time and the split between

upstream and downstream traffic is the same in each adjacent pico cell. This idea is illustrated schematically in Figure 5. This shows a series of transmissions for two adjacent pico-cells named PC1 and PC2. Downstream transmissions from AP to WT are represented by A and upstream transmissions from WT to AP are illustrated by B. Thus, each frame comprises portion A plus portion B.

As can be seen from the figure, portion A and portion B for each frame start and end at exactly the same time in PC1 and PC2. Because of this, interference between the two frames will be eliminated.

It will be seen, however, that the overall length of the frames changes with time and, that the proportion of the frame allocated to upstream and downstream transmissions also varies with time. This variation in frame length is achieved by monitoring the upstream and downstream traffic requirements of adjacent pico-cells at a central controller connected to the Access Points over a predetermined period of time and using this to determine the optimum frame length and split between upstream and downstream transmissions..

Delay Compensation

As explained above, WT's remote from the AP with which they are communicating will receive downstream data at a later time than WT's close to the AP. Thus, they will start to compute the Turnaround Time (TT1 in Figure 2) at a later time and thus will send their upstream transmissions at a later time. This will cause contention at the AP with transmissions from other WT's.

In order to overcome this, each WT is provided with a variable delay to insert between receipt of the downstream

transmission and the AP. The system is organised to set delays such that WT's close to the AP will have a delay inserted to simulate the effect of that WT being at the maximum possible distance from the AP.

Initially, all mobiles have no delay information. The first transmission that a mobile can make is in the Reservation Request slot and the default transmission delay is 0. This means that the Reservation Request may appear early to the AP, but can only collide with other Reservation Requests from other mobiles in the normal way. The acknowledgement of Reservation Requests and data cells by the AP includes delay correction information so that the mobile can then synchronise to the appropriate delay.

CLAIMS

1. A method for prioritising data transmissions in a radio communication system having at least one base station and at least one remote station wherein the base station can transmit signals to and receive signals from the remote station whilst the remote station is in a predetermined area, the method comprising the steps of:

assigning a priority to each type of data to be transmitted;

determining the type and priority of each forthcoming transmission;

storing data relating to forthcoming transmissions for each data type; and

transmitting data types with the highest priority prior to data types with lower priorities.

2. A method according to claim 1 in which transmissions between the base station and the remote station comprises a series of time periods each having a first portion during which the base station broadcasts signals and a second portion during which remote stations transmit data to the base station in pre-allocated time slots in each time period, and wherein time slots in each time period are allocated to data transmissions in dependence on the priority assigned to the data type to be transmitted to or from each remote station.

3. A method according to claim 2 wherein the base station transmits signals to and receives signals from a plurality of remote stations and time slots in each time period are allocated to transmissions between the base station and, individual remote stations in dependence on

the priority assigned to the data type to be transmitted and the time at which a request for that transmission was made.

4. A method according to claim 2 or 3 comprising the step of transmitting constant bit-rate data between the base station and at least one remote station and allocating at least some of the time slots in each time period to transmissions of the constant bit-rate data.

5. A method for radio communication for use with a plurality of overlapping communication cells, each cell comprising a base station and at least one remote station and wherein the base station broadcasts signals in a first time period and remote stations transmit signals to the base station in a second time period, and wherein the base stations in each cell are coupled to a central controller, the method comprising the steps of:

synchronising the first and second time periods used by base stations in adjacent cells;

monitoring the transmissions in each cell; and

adjusting the durations of each of the first and second time periods to improve use of the available transmission bandwidth whilst retaining synchronisation of the first and second time periods between adjacent cells.

6. A method for radio communication between a base station and a plurality of remote stations wherein the base station can transmit signals to and receive signals from the plurality of remote stations, the method comprising the steps of:

broadcasting signals from the base station to the remote stations during a first time period;

transmitting signals from the remote stations to the base station after a predetermined delay; and

varying the delay in dependence on the distance of the remote station from the base station.

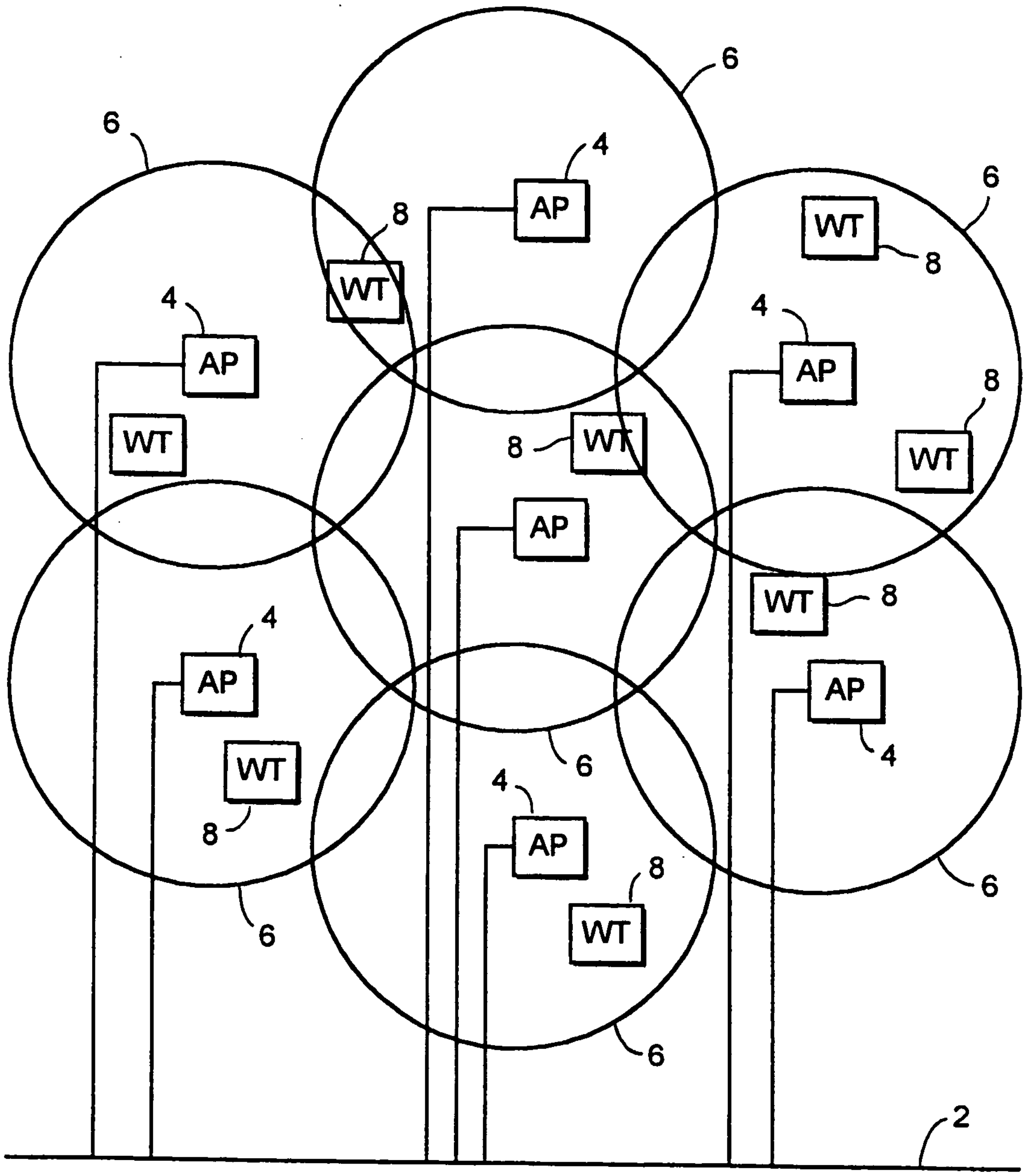
6
6
4
AP
8
WT
6
WT
8
4
AP
4
AP
8
WT
WT
8
AP
WT
WT
8
4
AP
AP
4
WT
6
8
4
AP
8
6
WT
6
6
2

FIG. 1

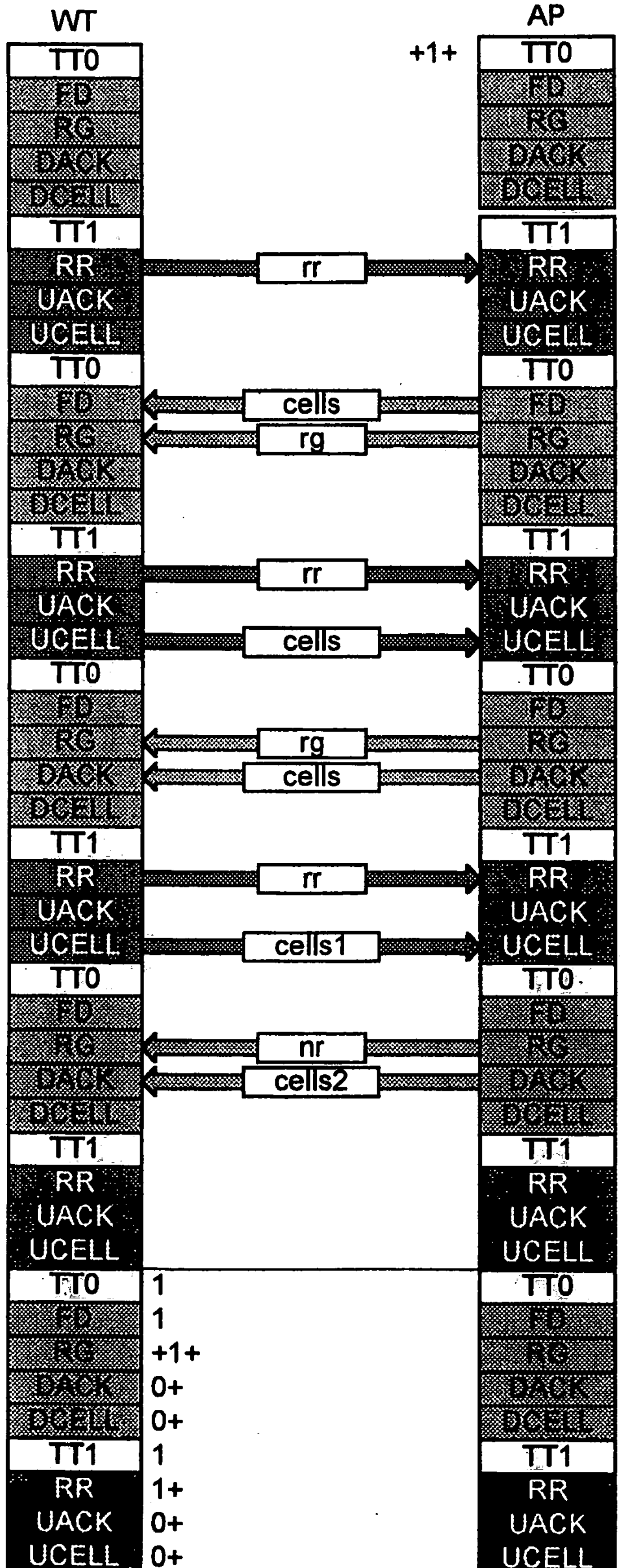
WT
AP
+1+
TT0
FD
RG
DACK
DCELL
TT1
RR
UACK
UCELL
rr
cells
rg
cells1
nr
cells2
1
+1+
0+
1+

FIG. 2

	WT TO AP			AP TO WT			
	DT1	DT2	DT3	DT1	DT2	DT3	ANTENNA
WT5	F / N	F / N	F / N	F / N	F / N	F / N	X
WT4	F / N	F / N	F / N	F / N	F / N	F / N	X
WT3	F / N	F / N	F / N	F / N	F / N	F / N	Y
WT2	F / N	F / N	F / N	F / N	F / N	F / N	X
WT1	F / N	F / N	F / N	F / N	F / N	F / N	Y

FIG. 3

WT TO AP			AP TO WT		
DT1	DT2	DT3	DT1	DT2	DT3
WT1			WT4		
WT5		WT4	WT1	WT5	
WT3	WT5	WT3	WT3	WT1	WT3
WT4	WT2	WT1	WT5	WT3	WT4

FIG. 4

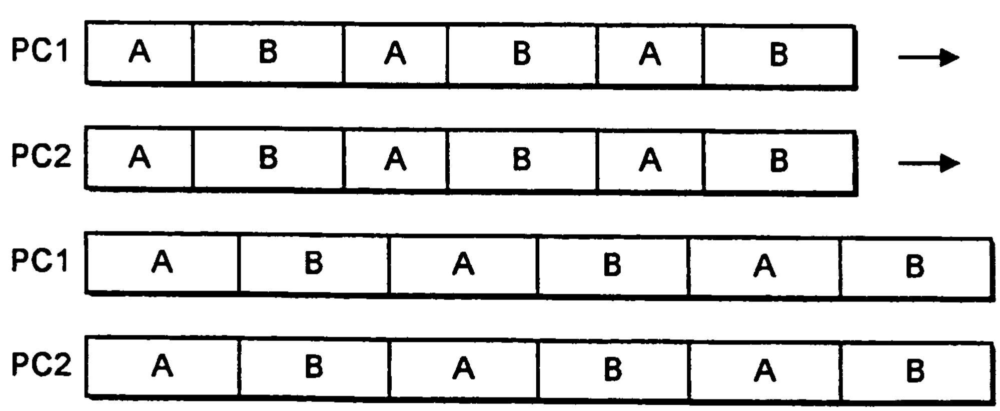

FIG. 5